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Stability & Control Aspects of UCAV Configurations

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13. SUPPLEMENTARY NOTES

See also ADM001685, CSP 02-5078, Proceedings for Aerodynamic Issues of Unmanned Air Vehicles (UAV)., The original document contains color images.

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UAV Classifications & Roles

Micro

Tactical EW

Combat

URAV

UCAV

ISTAR

Targets

Tactical

Strategic

Stability & Control of UAV Configurations

- **Most UAV Configurations Are Relatively Conventional**
  - Unswept or low sweep wing
  - Conventional tailplane
  - Conventional fin or fins
- **These Configurations Pose No Unusual Stability & Control Problems**
  - Conventional configurations give conventional S&C characteristics
- **However, One Class of UAVs Is Driven to Very Unconventional Configurations**
  - Uninhabited combat air vehicles (UCAV) configurations are being driven by considerations other than aerodynamic ones
  - This class of UAVs pose many unusual stability & control problems

UCAV Concept

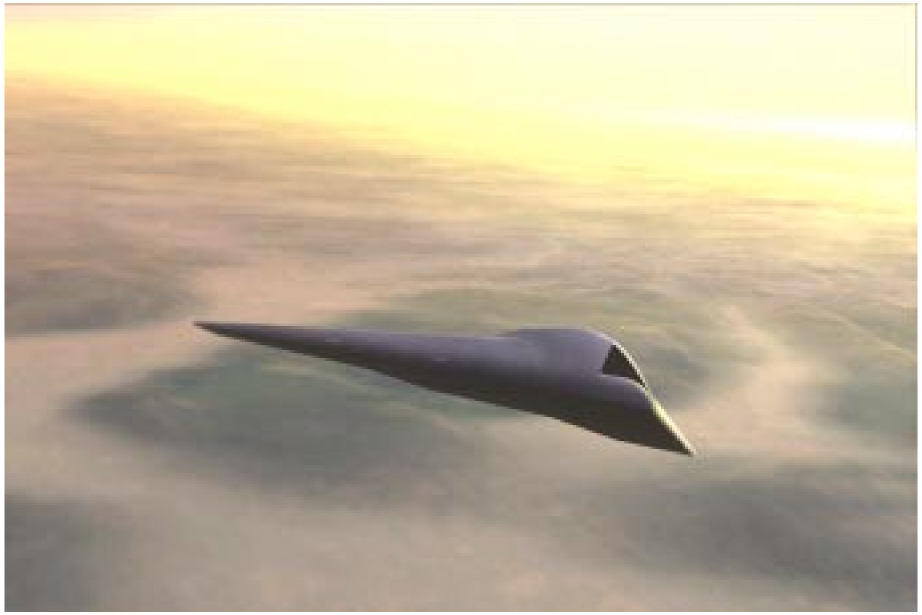
- **UCAVs Are Being Conceived As Ground Attack Weapon Platforms**
  - Deep strike
  - Suppression of enemy air defences
- **These Aircraft Configurations Are Driven By**
  - Survivability
  - Long range
  - Air-to-ground weapon payload
  - Subsonic
  - Medium altitude
  - Modest manoeuvrability

Stability & Control of UCAV Configurations

- **These Requirements Result in Unusual Aircraft Configurations, With Unusual & Challenging Stability & Control Characteristics**

- **Typically**
  - Highly swept & tapered wings
  - Cranked wings
  - Blended wing body
  - No fin
  - No tailplane
  - Novel control surfaces

- **For Example:**

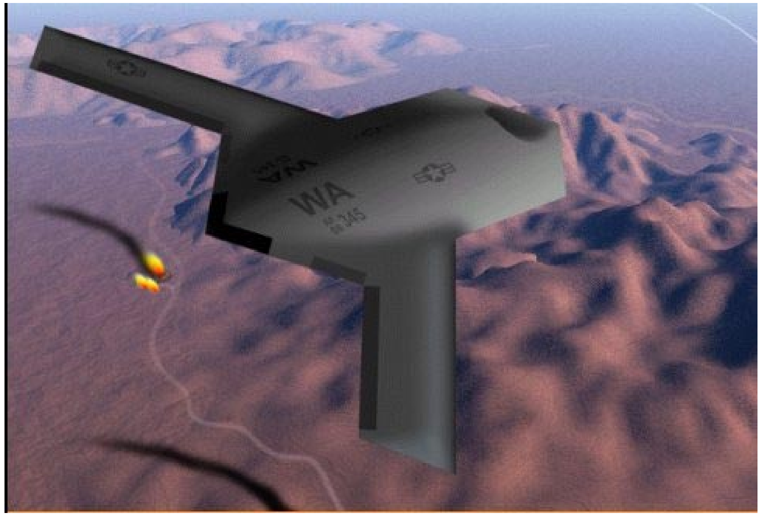


Example of Modern UCAV Configuration

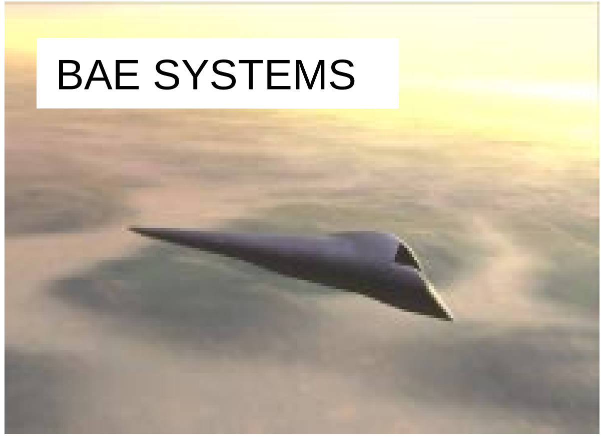
- Very high leading edge sweep (55°)
- High trailing edge sweep (30°)
- No fin
- No tailplane
- Blended wing-body
- No forebody
- Elevons for pitch & roll control
- ‘Inlaid surfaces’ (spoilers) for yaw control

Example of Modern UCAV Configuration (2)

- High leading edge sweep (43°)
- Very high trailing edge sweep (43°)
- Lambda wing
- No fin
- No tailplane
- Blended body
- Elevons for pitch & roll control
- Thrust vectoring and ‘dragerons’ for yaw control



Other UCAV Concepts



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Dassault AVE

Aurora Flight Sciences

EADS

SAAB Sharc

Boeing X-46 UCAV-N

S&C Challenges- No Fin

- **The Choice of a Finless Configuration Is Driven by Considerations Other Than Aerodynamics.**
- **This Results in an Aircraft Which Is Directionally Unstable in Yaw Throughout the Flight Envelope.**
  - Feedback FCS can provide artificial stability, within limits
  - Aircraft must be carefully designed to avoid excessive levels of instability (can't 'fix' design by making fin bigger)
- **Need Alternative Yaw Controls to Replace Conventional Rudders.**
  - Yaw thrust vectoring
  - Alternative aerodynamic controls

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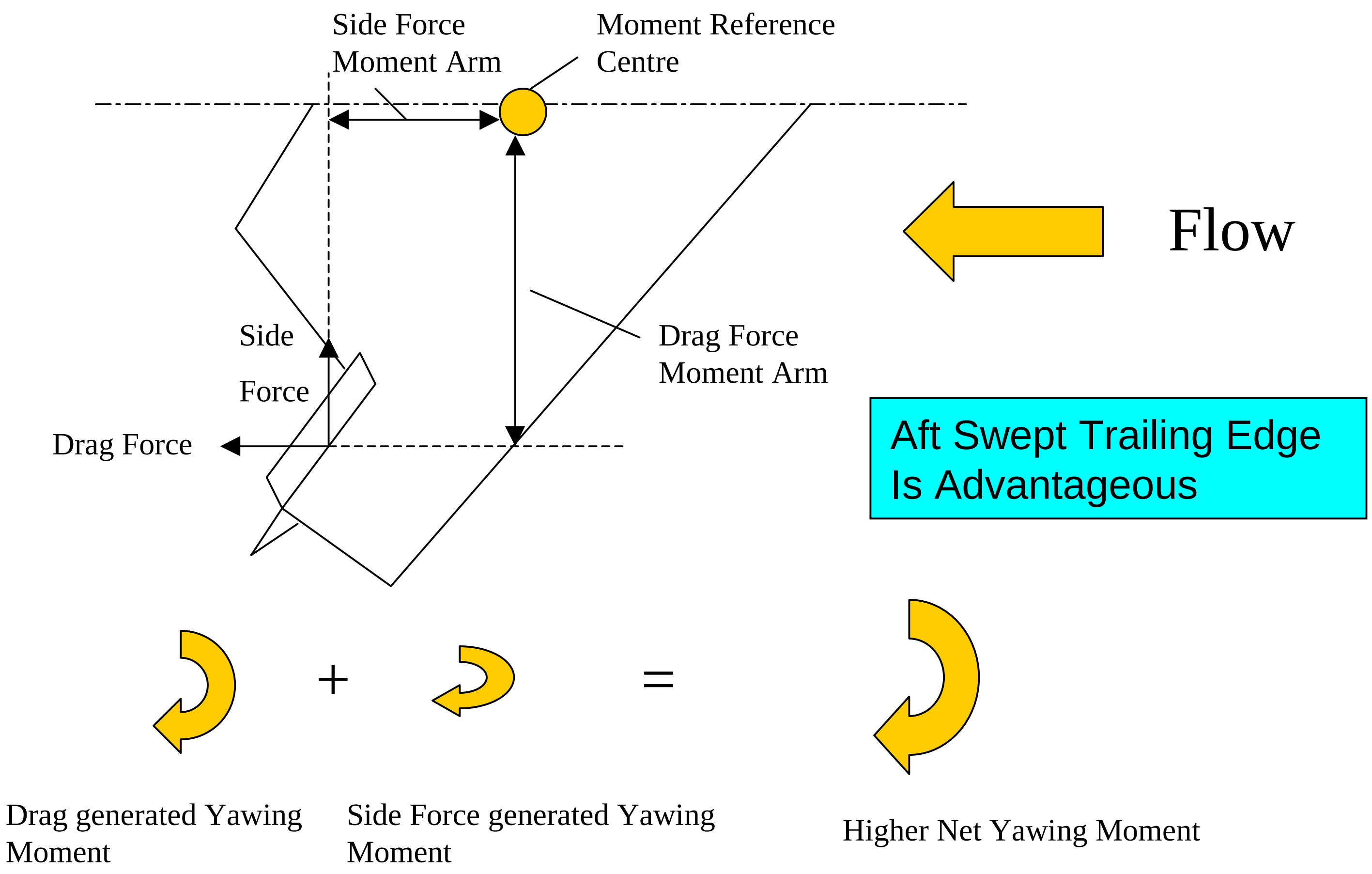
S&C Challenges - Yaw Thrust Vectoring

- **Thrust Vectoring is Extremely Effective in Flight Conditions Where Thrust Is High Compared to the Dynamic Pressure.**
- **However, Thrust Vectoring Is Ineffective in Flight Conditions Where the Thrust Is Low in Comparison to the Dynamic Pressure.**
  - Landing Approach
  - Dive Manoeuvres
  - Deceleration
- **The Need to Fly in Such Flight Conditions (Particularly Landing Approach) Leads to the Conclusion That Thrust Vectoring Is Not Viable As the Sole Means of Control in Any Axis, and That Additional Aerodynamic Means of Control Is Required.**
  - This Additional Aerodynamic Control Also Strengthens the Safety Case, Given That Thrust Vectoring Relies on the Engine, and Turbomachinery Reliability is Significantly Lower Than Aerodynamic Flight Controls

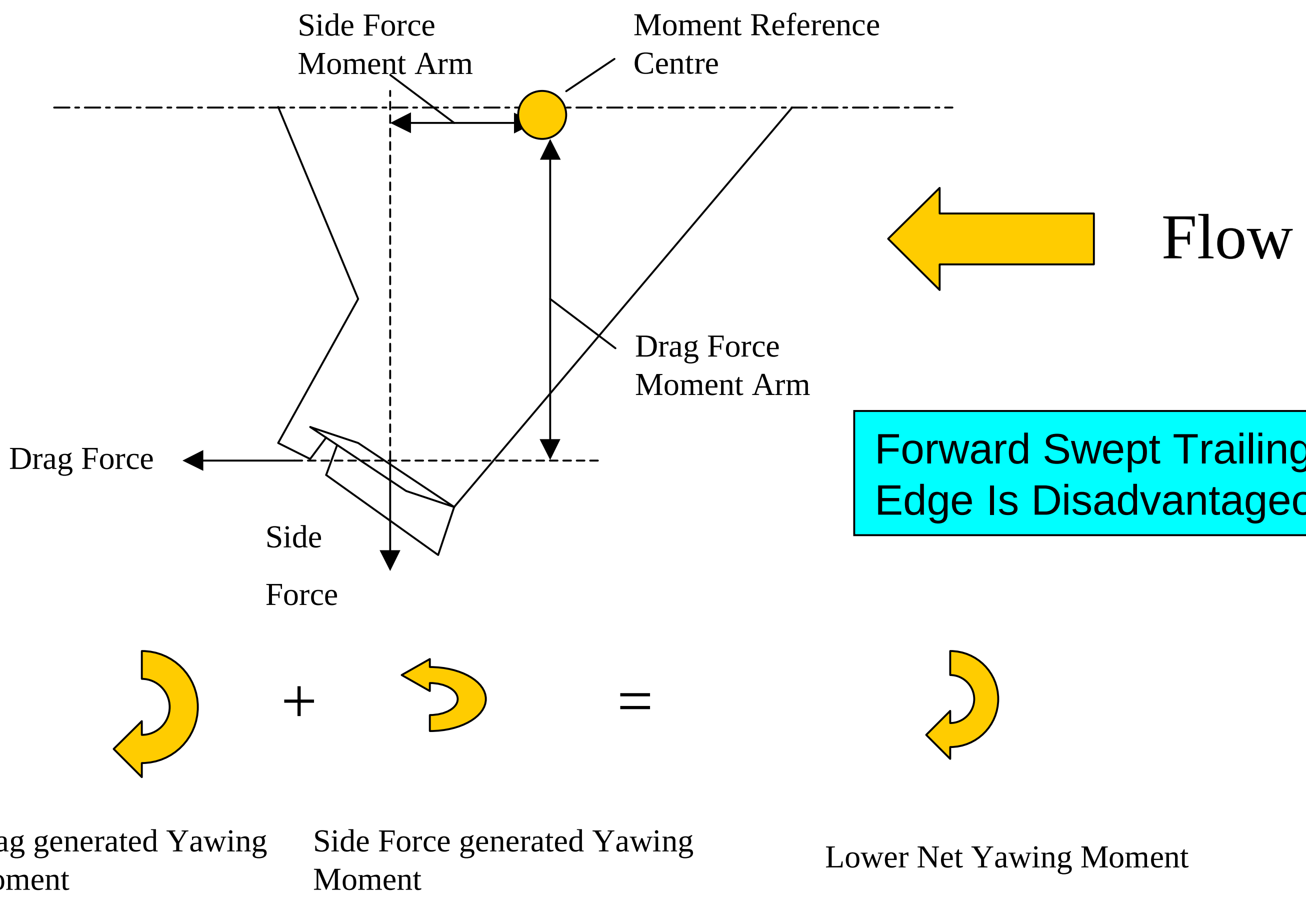
S&C Challenges - Alternative Yaw Controls

- **A Number of Aerodynamic Means of Yaw Control (Other Than Rudders) Have Been Conceived:**
  - Split Flap Drag Rudders (e.g. B-2, X-36, X-45) - Poor Effectiveness on Trailing Edges With Forward Sweep Angles.
  - All-moving-wingtips (Lockheed Martin Research) - Need Large Deflections to Be Effective.
  - Spoilers (e.g. X-47) - Sweep Independent of Trailing Edge, But Large Rolling Moments
- **All These Work by Inducing Differential Drag.**
  - Spoil Wing Lift (Produce Roll & Pitch as Well as Yaw)
- **Pitch, Roll And Yaw Control All Provided By Wing Controls.**
  - Strongly Cross-Coupled
  - Control Allocation is Not Trivial
  - Limited Wing Span to Accommodate all Necessary Controls

S&C Challenges : Split Flap Drag Rudders



S&C Challenges: Split Flap Drag Rudders



Forward Swept Trailing Edge Is Disadvantageous

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S&C Challenges - Highly Swept Wings

- **High Wing Leading Edge Sweep Angles Give Strong Dihedral Effect.**
  - Very Stable $Cl\beta$
  - Can Cause Poor Dutch Roll Characteristics
  - Requires More Roll Control to Trim Crosswinds
- **High Trailing Edge Sweep Angles Give Poor Roll Control Effectiveness.**
- **So Roll Control Almost As Demanding As Yaw Control**
  - Need Large Roll Control Surfaces
- **Combined with Need for Wing Yaw Controls, Makes Control Sizing Very Demanding**

S&C Challenges - Unusual Wing Planforms

- **Typically UCAV Configurations Have Highly Tapered and/or Cranked Wing Planform Shapes**
  - Lambda Wings
  - Cropped Trapezoidal Wings
- **These Shapes Have Poor Flow Characteristics at ‘High’ Angles of Attack**
- **Typically Have Poor Pitch Stability Characteristics**
  - Severe Pitch-Up Non-Linearities
  - Can be Exacerbated by Yaw Controls
- **With No Tailplane or Foreplane Have Limited Pitch Control Power to Deal With These Non-Linearities**

S&C Challenges - Blended Wing Body

- **Typically UCAV Configurations Are Highly Blended Wing-Bodies or Pure Flying Wings**
- **Directional Instability Level is Key Design Constraint**
  - Also Sizes Yaw Controls
- **Traditional Empirical Prediction Methods Estimate Directional Stability From Size & Shape of Fin and Axi-Symmetric Forebody**
  - These Methods Can't Be Used for Blended Wing Body
- **Very Difficult to Estimate Directional Instability Prior To Wind Tunnel Testing**
  - Very Expensive If Major Design Change Needed at This Stage!

S&C Challenges - No Forebody

- **Many Candidate UCAV Configurations Have No Forebody.**
  - Pure Flying Wings
- **However, This Makes Longitudinal Balance Very Difficult.**
  - Need Aerodynamic Centre Close to CG
  - Stability/Instability Must Be Within Acceptable Bounds
- **CG Must Be Placed Near 25% MAC**
- **Very Difficult to Get Sufficient Mass Forward of 25% MAC.**
  - Jetpipe & Control Surface Actuators at Back
  - Engine in Centre
  - Fuel & Stores Around CG
  - Everything Else at Front!
- **Volume At Aft of Aircraft Cannot be Efficiently Utilised.**

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Conclusions

- **Most UAV Configurations Are Conventional, Aerodynamically Driven Shapes, with Conventional Stability & Control Characteristics.**

- **However, the Requirements of Combat UAVs (UCAVs) Drive To Radical Configurations With Unusual Stability & Control Challenges.**
  - Finless: Directionally Unstable
  - Rudderless: Novel Yaw Controls; Cross-Coupled Non-Linear Controls
  - High Wing Sweep: Demanding Roll Control
  - Unusual Wing Shapes: Pitch Non-Linearities
  - Blended Wing-Bodies: Difficult to Predict Directional Instability
  - No Forebody: Difficult Longitudinal Balance

- **Stability & Control Issues Must Be Addressed Early In The UCAV Design Cycle.**